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**FINAL REPORT FOR
NASA TRAINING GRANT NGT-50866**

The NASA GSRP grant NGT-50866 was awarded to support research on x-ray optics. During the third year under GSRP support, progress was made in the development of an experimental model and theoretical technique to determine "optical behavior" values of x-ray materials to be used in x-ray multilayer design. Also, spectroscopic tomographic x-ray instrumentation for chemical composition analysis, detection and localization was developed.

Advances in x-ray optical technology have been limited by the fact that most materials are transparent to x-rays. Because the value of the index of refraction is close to unity, a large number of very thin layers are required to achieve an adequate amount of reflected energy. Using ideal handbook values for the optical constants, the theoretical values for the reflectance are very different from measured values. We have developed an experimental model and theoretical technique to determine new optical constants or "optical behavior" values for substrate and thin film materials. These values include all imperfections that make a real film different from an ideal film. Deposition conditions, surface roughness, volume inhomogeneities, contamination and interdiffusion layers all act to make a real film different from an ideal film. We've incorporated all of these imperfections into the optical constants.

X-ray reflectance measurements were taken at NIST in Gaithersburg, MD. Comparing these measurements with theoretical reflectance values, the optical constants were changed until the difference between these values was a minimum. Measurements were taken for the substrate, single films of Mo and Si, and two film combinations of Si on

Mo and Mo on Si. Optical behavior values were reported and the results were analyzed to determine the best combination of film materials. We found that when Mo was deposited on Si, the interdiffusion layer between the two materials had little effect on the reflectance, and the optical constants. However, when Si was deposited on Mo, the reflectance values were very different, leading to changes in the optical constants. Thus, the interdiffusion layer affects the reflectance differently when Si was deposited on Mo compared to when Mo was deposited on Si.

New values for the optical constants will allow for the correct prediction of the spectral performance of an x-ray multilayer. Although the optical behavior values vary from chamber to chamber and deposition process to deposition process, the method can be used to determine optical behavior values for any chamber and any deposition process.

X-ray instrumentation designs were developed using spectroscopy and tomography to determine the chemical composition and localize suspicious objects. Three narrowband x-ray filters designed for different energies and oriented at different angles provide information about the chemical composition of each volume pixel in an entire volume. Such instrumentation has applications in mammography, chip inspection, and luggage inspection.

Publications and Presentations

The following papers on optical constant determination and sliced multilayer designs were presented and published in SPIE proceedings:

"Optical Behavior Determination of Thin Film and Bulk Materials in the X-Ray Region," M. M. Wilson, M. Zukic, D. G. Torr, A. J. Fennelly, E. L. Fry, *Advances in Multilayer and Grazing Incidence X-Ray/EUV/FUV Optics*, Proc. SPIE 2279, in press, July, 1994.

"Sliced Multilayer Grating X-Ray Spectroscopy," M. M. Wilson, M. Zukic, D. G. Torr, A. J. Fennelly, E. L. Fry, *X-Ray and Ultraviolet Spectroscopy and Polarimetry*, Proc. SPIE 2283, 189-199, 1994.

"Optical Constant Determination for X-Ray Materials," M. Wilson, J. Kim, M. Zukic, D.G. Torr, *X-Ray and Ultraviolet Polarimetry*, Proc. SPIE 2010, 211-219, 1993.

Michele Wilson graduated on December 18, 1994.